



**SOUTHERN MAPPING®
GEOSPATIAL**

Selborne House | Roos Street | Fourways | 2068 | RSA

Mokolo Crocodile Water Augmentation Project Phase 2

GBN Joint Venture

SGP2019_43

Final Survey Report



15 January 2020

Contents

Project Detail, Overview and Equipment Used	3
Project Detail.....	3
Project Overview.....	3
Equipment Used.....	3
Project Extent.....	4
Ground Control Points	5
LiDAR Point Processing, Calibration, Transformations & Editing	7
LiDAR Point Processing	7
LiDAR Point Calibration	7
LiDAR Point Transformations	7
Orthophoto Rectification Procedure	8
Accuracies	9
Vertical Accuracy.....	9
Horizontal Accuracy	9
Overlapping Project Comparison	10
Deliverables.....	11
Queries	12
Appendix 1	13

Project Detail, Overview and Equipment Used

Project Detail

Survey Project: Mokolo Crocodile Water Augmentation Project Phase2
Date of Survey: 15th and 18th November 2019.
Client: GBN Joint Venture.

Project Overview

In 2009 Southern Mapping performed an aerial Lidar survey over the proposed pipeline route and had a ground survey done by MHP Geomatics in which all of the points were levelled. Over the years some changes were made to the original route. This project involves the survey of several borrow pits, some centerline changes and a new set of orthophotos for the route.

The handover lidar data had to match the original 2009 data.

In 2009 the accuracy of the available geoid model (SA Quasi) was limited and the lidar data was converted from ellipsoidal to orthometric heights using a custom geoid. This custom geoid was created from the level points.

In 2019 the entire route was flown with both lidar and imagery. The images were used to create the new orthophotos and the lidar used for the new areas. It should be noted that the lidar is available for the entire route and it only needs to be checked and edited for use in the final design. The survey was flown at a height of approximately 850m and images with an 8cm pixel resolution were taken.

The ground survey points from 2009 were checked for accuracy by Trail Surveys and Mapping after the flights. The points that were found to have moved were rebuilt and resurveyed. Some points were also added and surveyed.

Equipment Used

Aircraft: Cessna F406 (ZS-SSY).
Laser Scanner: Optech Orion M300 (12SEN306).
Camera: IXU RS-1000 Phase One.

Project Extent

The total of the surveyed project area is approximately 2 105 ha and 140km with an 800m delivery strip width.



Locality Map

Ground Control Points

Ground control points were surveyed by Trail Surveys. This full coordinate list contains original verified points, resurveyed points and new points. Where the final height was obtained from GNSS measurements, the SAGEoid2010 model was used. Photographs have been provided in a separate submission by Trail Surveys.

MCWAP PHASE 2 PIPELINE Final Beacon Coordinate List

Ellipsoid: WGS84
Datum: Hartebeesthoek94
Zone: Lo27°
Geoid: SA Geoid 2010



TRAIL SURVEYS

NAME	Y	X	Z	BEACON DESCRIPTION	HEIGHT DESCRIPTION
A09220022N	-62 833.077	2 620 731.436	865.53	12mm iron peg in conc	GPS-NEW
A09220024N	-61 169.737	2 621 667.569	875.98	12mm iron peg in conc	GPS-NEW
A09220031	-51 610.738	2 623 074.563	918.432	12mm iron peg in conc	LEVEL-ORIGINAL
A09220032AN	-47 624.203	2 623 444.867	922.30	12mm iron peg in conc	GPS-NEW
A09220032N	-49 622.582	2 623 274.319	915.36	12mm iron peg in conc	GPS-NEW
A09220033N	-46 218.499	2 624 235.565	933.14	12mm iron peg in conc	GPS-NEW
A09220034N	-45 354.777	2 624 880.611	944.37	12mm iron peg in conc	GPS-NEW
A09220035N	-43 798.645	2 625 944.202	949.86	12mm iron peg in conc	GPS-NEW
A09220056N	-41 374.833	2 642 613.398	1007.06	12mm iron peg in conc	GPS-NEW
A09220057	-41 143.582	2 643 611.552	1016.164	12mm iron peg in conc	LEVEL-ORIGINAL
A09220058N	-40 698.438	2 645 594.065	1018.88	12mm iron peg in conc	GPS-NEW
A09220059N	-40 246.365	2 647 519.041	1013.85	12mm iron peg in conc	GPS-NEW
A09220060	-39 840.527	2 649 408.140	993.778	12mm iron peg in conc	LEVEL-ORIGINAL
A09220061	-40 083.019	2 651 345.223	987.849	12mm iron peg in conc	LEVEL-ORIGINAL
A09220062	-40 413.038	2 653 279.106	980.843	12mm iron peg in conc	LEVEL-ORIGINAL
A09220063	-40 753.721	2 655 246.361	963.695	12mm iron peg in conc	LEVEL-ORIGINAL
A09220064	-41 079.776	2 657 136.394	939.138	12mm iron peg in conc	LEVEL-ORIGINAL
A09220065	-41 407.659	2 659 084.863	949.501	12mm iron peg in conc	LEVEL-ORIGINAL
A09220066	-41 741.660	2 661 060.358	949.020	12mm iron peg in conc	LEVEL-ORIGINAL
A09220067	-42 090.153	2 663 045.922	941.995	12mm iron peg in conc	LEVEL-ORIGINAL
A09220068	-42 423.575	2 664 995.659	922.587	12mm iron peg in conc	LEVEL-ORIGINAL
A09220069	-42 896.105	2 666 938.495	954.543	12mm iron peg in conc	LEVEL-ORIGINAL
A09220070	-43 388.202	2 668 884.942	953.314	12mm iron peg in conc	LEVEL-ORIGINAL
A09220071	-43 912.648	2 670 919.483	950.238	12mm iron peg in conc	LEVEL-ORIGINAL
A09220072	-44 414.411	2 672 865.323	969.684	12mm iron peg in conc	LEVEL-ORIGINAL
A09220073	-44 924.858	2 674 843.419	977.371	12mm iron peg in conc	LEVEL-ORIGINAL
A09220074N	-45 423.730	2 676 775.667	980.85	12mm iron peg in conc	GPS-NEW
A09220075	-45 701.712	2 678 737.364	988.202	12mm iron peg in conc	LEVEL-ORIGINAL
A09220076	-45 689.394	2 680 742.265	993.310	12mm iron peg in conc	LEVEL-ORIGINAL
A09220077	-45 672.879	2 682 660.636	1002.331	12mm iron peg in conc	LEVEL-ORIGINAL
A09220078	-45 653.098	2 684 672.895	1012.347	12mm iron peg in conc	LEVEL-ORIGINAL

NAME	Y	X	Z	BEACON DESCRIPTION	HEIGHT DESCRIPTION
A09220078A	-45 634.554	2 686 700.016	1020.007	12mm iron peg in conc	LEVEL-ORIGINAL
A09220079N	-45 626.308	2 687 556.902	1017.66	12mm iron peg in conc	GPS-NEW
A09220080	-45 606.226	2 689 648.766	1012.530	12mm iron peg in conc	LEVEL-ORIGINAL
A09220081	-45 587.501	2 691 670.933	1020.250	12mm iron peg in conc	LEVEL-ORIGINAL
A09220082	-45 566.713	2 693 673.937	1034.620	12mm iron peg in conc	LEVEL-ORIGINAL
A09220083N	-45 549.249	2 695 618.161	1038.83	12mm iron peg in conc	GPS-NEW
A09220084N	-45 528.778	2 697 781.321	1040.05	12mm iron peg in conc	GPS-NEW
A09220085	-44 308.035	2 698 751.636	1051.790	12mm iron peg in conc	LEVEL-ORIGINAL
A09220086	-42 378.166	2 699 633.610	1076.440	12mm iron peg in conc	LEVEL-ORIGINAL
A09220088	-40 654.126	2 700 407.550	1075.970	12mm iron peg in conc	LEVEL-ORIGINAL
A09220089	-41 266.495	2 702 420.232	1100.503	12mm iron peg in conc	LEVEL-ORIGINAL
A09220090	-39 395.870	2 702 898.007	1118.065	12mm iron peg in conc	LEVEL-ORIGINAL
A09220091N	-38 409.184	2 703 540.266	1085.34	12mm iron peg in conc	GPS-NEW
A09220092N	-36 424.194	2 704 398.134	1052.38	12mm iron peg in conc	GPS-NEW
A09220093N	-34 503.596	2 705 276.751	1023.15	12mm iron peg in conc	GPS-NEW
A09220094N	-32 847.041	2 706 032.297	1003.42	12mm iron peg in conc	GPS-NEW
A09220095N	-31 577.925	2 706 612.904	989.06	12mm iron peg in conc	GPS-NEW
A09220096	-30 234.960	2 707 329.199	976.795	12mm iron peg in conc	LEVEL-ORIGINAL
A09220101	-27 427.448	2 713 169.529	939.335	12mm iron peg in conc	LEVEL-ORIGINAL
A09220102	-28 471.850	2 714 615.660	942.651	12mm iron peg in conc	LEVEL-ORIGINAL
A09220103	-29 777.234	2 716 399.931	951.191	12mm iron peg in conc	LEVEL-ORIGINAL
A09220104	-30 853.969	2 717 896.288	956.898	12mm iron peg in conc	LEVEL-ORIGINAL
A09220113	-31 596.402	2 725 329.102	907.809	12mm iron peg in conc	LEVEL-ORIGINAL
A09220127	-32 658.295	2 721 001.488	977.245	12mm iron peg in conc	LEVEL-ORIGINAL
A09220128	-31 603.716	2 719 732.969	956.183	12mm iron peg in conc	LEVEL-ORIGINAL
A09220310A	-41 588.260	2 641 621.410	992.750	12mm iron peg in conc	LEVEL-ORIGINAL
A09220311N	-42 025.934	2 639 681.774	978.16	12mm iron peg in conc	GPS-NEW
A09220312	-42 485.900	2 637 657.580	954.410	12mm iron peg in conc	LEVEL-ORIGINAL
A09220313	-42 924.430	2 635 660.900	948.950	12mm iron peg in conc	LEVEL-ORIGINAL
A09220314	-43 373.690	2 633 701.120	937.730	12mm iron peg in conc	LEVEL-ORIGINAL
A09220315	-43 813.730	2 631 709.480	940.250	12mm iron peg in conc	LEVEL-ORIGINAL
A09220317	-43 997.400	2 630 881.800	937.340	12mm iron peg in conc	LEVEL-ORIGINAL
A09220317A	-42 907.040	2 629 174.900	949.620	12mm iron peg in conc	LEVEL-ORIGINAL
A0922078A	-45 634.524	2 686 699.964	1020.007	12mm iron peg in conc	LEVEL-ORIGINAL
MCWAP1	-31 950.547	2 725 059.540	915.744	12mm iron peg in conc	LEVEL-NEW
MCWAP2	-30 891.110	2 722 885.411	911.368	12mm iron peg in conc	LEVEL-NEW
MCWAP3	-29 921.604	2 720 968.735	916.292	12mm iron peg in conc	LEVEL-NEW
MCWAP4	-28 083.562	2 712 904.520	944.883	12mm iron peg in conc	LEVEL-NEW
MCWAP5	-28 645.812	2 710 839.005	955.246	12mm iron peg in conc	LEVEL-NEW
MCWAP6	-28 903.569	2 709 873.811	960.952	12mm iron peg in conc	LEVEL-NEW
MCWAP8	-42 886.693	2 627 668.268	952.216	12mm iron peg in conc	LEVEL-NEW
MCWAP9	-53 621.281	2 622 601.862	912.563	12mm iron peg in conc	LEVEL-NEW
MCWAP10	-56 117.493	2 621 952.262	900.735	12mm iron peg in conc	LEVEL-NEW
MCWAP11	-58 663.759	2 621 486.843	889.288	12mm iron peg in conc	LEVEL-NEW
MCWAP12	-60 012.981	2 620 624.229	876.872	12mm iron peg in conc	LEVEL-NEW

There are 45 existing points with original levels, 20 new points with gps heights and 11 new points with levelled heights

LiDAR Point Processing, Calibration, Transformations & Editing

LiDAR Point Processing

The trajectories were calculated from the Trignet stations at Ellisras and Nylstroom. The trajectory for each flight was post processed using *POSPac MMS* software and outputs a smoothed “best estimated” trajectory for the laser scanner and camera positions.

Subsequently, the LiDAR points were processed into raw ENH points, using Optech’s *LMS* Survey Suite.

LiDAR Point Calibration

Overlapping LiDAR points from adjacent aircraft trajectories were used to check the LiDAR calibration for heading, roll, pitch and scale.

These values were then used to make small flight-specific adjustments to the LiDAR data.

LiDAR Point Transformations

The survey was originally calculated on the ITRF2014 (WGS84) datum and WG27 projection. The survey was converted to the Hartebeesthoek94 datum using the Ellisras and Nylstroom Trignet shift values in the table below.

	Known Y	Known X
Shift (m)	0.35	0.54

To transform the ellipsoidal elevations to orthometric elevations, a custom geoidal model from the 2009 Mokolo & Crocodile Water Augmentation Water Project was used. The model was produced from points that had levelled heights and Lidar derived heights to determine the geoidal height differences.

This GPS and level survey was done by a private company, MHP Geomatics. Their report and data files were supplied with the 2009 handover data in hardcopy and digital format.

Appendix 1 provides a list of points used in the geoidal model.

LiDAR Point Editing

A first run automatic classification was carried out on the raw LiDAR points using *TerraSolid’s TerraScan* software to classify the LiDAR points into ground hits and non-ground hits. This results in a greater than 80% correct classification. After this, a strenuous manual classification was

carried out over the required area to edit the points thus minimizing gross classification errors that may have occurred in the automatic classification process.

Every LiDAR point has been classified according to the project requirement. A classification assigned to it that defines the type of object that has reflected the laser pulse.

Orthophoto Rectification Procedure

Images were rectified by identifying common pixel points in overlapping image tiles using a process known as tie-pointing.

After completion of the tie-point process, all images were adjusted for optimum heading, roll, pitch and scale values so as to ensure a seamless image mosaic was obtained. The image tiles are 800m square in size and were output with a pixel size of 8cm in ECW format.



Rectified Image

Accuracies

Vertical Accuracy

The check between the final handover lidar points and the original control points is relatively difficult as there has been a long time between the production of the two data sets. As the orthometric heights have been created using the control points, it is incorrect to use the same parameters to check the output.

Therefore we have produced a 2019 Lidar ground surface data set using the most modern and accurate geoid model SAGEoid2010. We have then compared the heights with the orthometric heights derived by Trail Surveys from a mixture of levelling and GNSS methods.

It should also be noted that some of the new beacons built by Trail Surveys were only constructed after the aerial flights. In some of these cases the ground surface has changed significantly. The photographs supplied by Trail Surveys in their submission show the potential changes.

The full results are shown in Appendix 2.

The summary results in meters are as follows:

Average dz	+0.017
Minimum dz	-0.163
Maximum dz	+0.112
Average magnitude	0.056
Root mean square	0.070
Std deviation	0.069

Therefore the independent check results are within the project acceptable values.

Horizontal Accuracy

Pre-marked check points were digitized on the orthophotos and the derived coordinates were compared with the ground survey values. Only four pre-marks were visible at the time of aerial survey. The results show that the final orthophotos with a 10cm pixel size match the ground based coordinates very well.

The results are as follows:

Coordinate system: Hartebeesthoek94 WG27

Name	Known Y	Known X	Orthophoto Y	Orthophoto X	dY (m)	dX (m)	distance (m)
A09220127	32 658.28	-2 721 001.47	32 658.31	-2 721 001.51	0.03	-0.04	0.05
A09220088	40 654.14	-2 700 407.54	40 654.18	-2 700 407.59	0.04	-0.05	0.07
A09220071	43 912.68	-2 670 919.49	43 912.69	-2 670 919.50	0.01	-0.01	0.02
A09220313	42 924.44	-2 635 660.91	42 924.43	-2 635 660.86	-0.01	0.05	0.05
Average from known position					0.02	-0.02	0.04
Maximum dY (m), dX (m) & dS (m)					0.04	0.05	0.07
Minimum dY (m), dX (m) & dS (m)					-0.01	-0.05	0.02
Standard deviation					0.02		

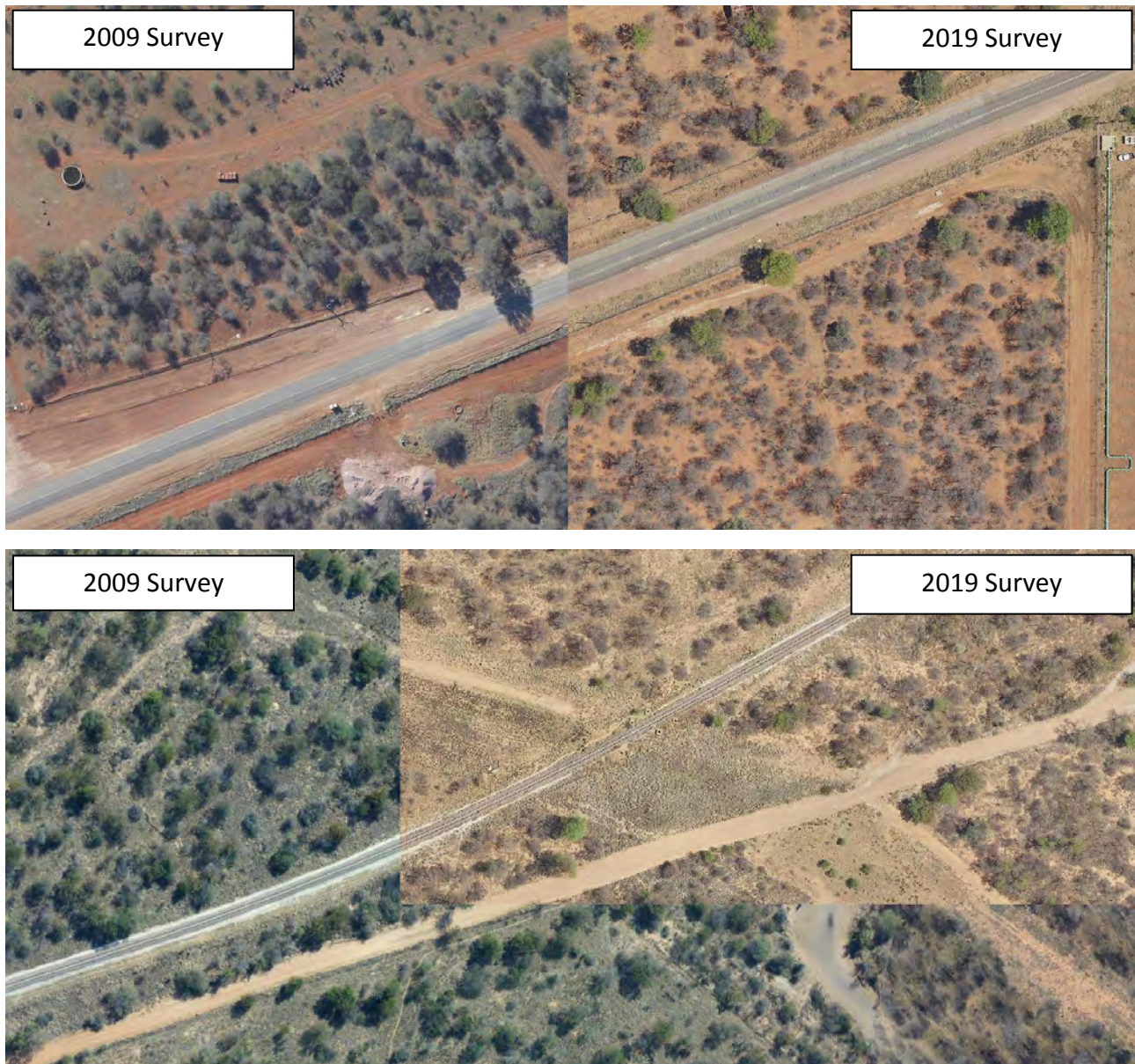
**Above is in CAD format*

Overlapping Project Comparison

As a further check on the data and its consistency, the aerial LiDAR survey was compared to previous work conducted in the same area in 2009.

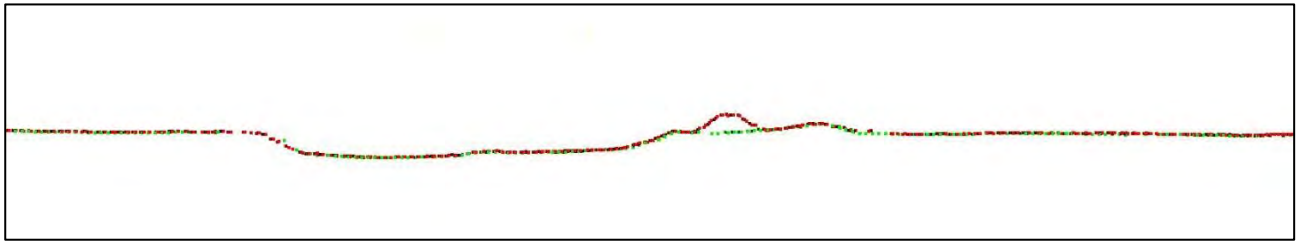
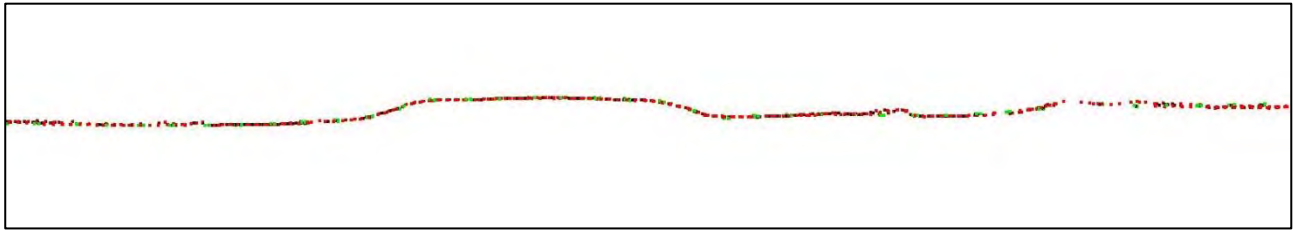
The resulting comparison is good and is illustrated below:

Image Comparison



LiDAR Comparison

LiDAR Comparison Examples – 2009 Ground Points (Green) and 2019 Ground Points (Red)



Deliverables

- CAD design files in Microstation DGN, DWG & DXF format showing:
 - i. Orthophoto tiles and LiDAR point block layout.
 - ii. The surveyed project area with boundaries.
 - iii. Contours at 0.5m, 1m and 2m intervals.

**These contours have been smoothed and are merely an aesthetic representation of the ground shape.*

- Ortho-rectified aerial images in ECW format with an 8cm pixel resolution.
- Composite Image in ECW format at 0.5m.
- 1m Raster DEM
- 1m Elevation Grid
- Google Earth Overlay in KMZ format at 0.5m.

- Full LiDAR points in ASCII (x, y, z) format with the following feature classes:
 - Ground
 - Low Vegetation
 - Medium Vegetation
 - High Vegetation
 - Powerlines
- This LiDAR Survey report as well as the Ground Survey Verification report from Trail Surveys.

*All of the above data are in the **Hartebeeshoek94 WG27 system**, with orthometric heights as calculated in TerraScan using a custom geoidal model attached in Appendix 1.*

Queries

In case of any queries please do not hesitate to contact:

Moshidi Mokgukulushi - LiDAR data processor	011 467 2609 or moshidi@southernmapping.com
Jacques Pieterse – Processing Manager [SAGC Registration Number: GTgGISc 1054]	011 467 2609 or jacques@southernmapping.com
Luana Hattingh – Detail Mapping Supervisor [SAGC Registration Number: GTgGISc 1040]	011 467 2609 or luana@southernmapping.com

Appendix 1

Survey points from MHP Geomatics 2009

Pt. ID.	Y	X	Z (Ellips)	(Ortho)
A09220001	-72039.778	2651737.579	1021.376	1003.604
A09220002	-70338.512	2651186.722	1113.778	1096.064
A09220003	-68989.929	2651887.880	1116.146	1098.414
A09220004	-67230.195	2651047.655	1056.495	1038.818
A09220005	-66436.122	2650686.661	1034.665	1016.997
A09220006	-65026.456	2649243.000	1018.918	1001.296
A09220007	-64155.370	2647781.965	994.354	976.786
A09220008	-64211.688	2645849.045	985.415	967.904
A09220009	-63620.294	2643851.374	1021.212	1003.783
A09220010	-64328.282	2642029.142	974.568	957.158
A09220011	-64606.372	2640945.897	986.128	968.729
A09220012	-63122.468	2639757.116	1026.324	1008.996
A09220013	-62601.563	2637779.461	927.986	910.740
A09220014	-62374.416	2635954.430	923.523	906.343
A09220015	-62131.505	2634091.546	960.906	943.789
A09220016	-62487.754	2632497.701	944.426	927.354
A09220017	-63189.783	2630731.217	915.580	898.577
A09220018	-63327.988	2628805.124	930.361	913.434
A09220019	-63255.668	2626883.356	903.875	887.016
A09220020	-63332.484	2624847.306	878.078	861.276
A09220021	-63546.668	2622860.110	889.344	872.630
A0922021A	-63769.804	2621517.603	881.824	865.146
A09220022	-62966.635	2620844.960	881.636	864.977
A09220023	-60877.350	2619141.994	891.937	875.342
A09220024	-61170.232	2621666.523	892.652	875.969
A09220025	-59479.308	2622286.402	906.117	889.419
A09220026	-59799.512	2622336.251	904.304	887.641
A09220027	-58128.258	2623305.318	912.177	895.405
A09220028	-56251.799	2623879.609	925.967	909.265
A09220029	-55419.397	2624214.233	929.911	913.205
A0922029A	-55581.893	2622940.448	922.915	906.241
A09220030	-53580.967	2623070.634	931.337	914.671
A09220031	-51610.738	2623074.563	935.091	918.432
A09220032	-49624.366	2623273.293	931.995	915.329
A0922032A	-47624.476	2623445.477	938.940	922.277
A09220033	-46221.091	2624234.158	949.798	933.131
A09220034	-45356.507	2624880.543	961.031	944.340
A09220035	-43799.417	2625944.270	966.762	950.044
A09220036	-42234.543	2625178.602	951.827	935.148
A09220037	-40789.064	2624394.670	947.161	930.505
A09220038	-38816.543	2623283.139	944.586	927.978
A09220039	-36830.085	2622164.025	932.274	915.735
A09220040	-34930.600	2622484.181	929.134	912.601
A09220041	-33255.071	2623359.288	933.826	917.270
A09220042	-31513.643	2624078.802	936.019	919.454
A09220043	-29705.399	2624826.500	941.122	924.548
A09220044	-27240.655	2622573.069	927.346	910.866
A09220045	-28306.080	2624462.010	939.745	923.215
A09220046	-34035.618	2622632.522	932.002	915.436
A09220047	-34721.966	2624432.945	939.849	923.238
A09220048	-35484.800	2626066.424	947.909	931.243
A09220049	-36367.300	2627503.814	956.722	940.038
A09220050	-37296.600	2629016.144	962.699	945.954
A09220051	-38100.836	2630526.670	974.078	957.290
A09220052	-38850.791	2632244.384	987.622	970.761

SGP2019_43_V02_GibbBigenNyeletiJointVenture_MokoloCrocodileWaterAugmentationProject_FinalSurveyReport

Southern Mapping Geospatial (Pty) Ltd

Revision0

Page 13 of 17



Reg. No. 2010/010712/07
 Directors: N Banks (Chairman),
 J P Engelke, J S Vaughan
www.southernmapping.com

A09220053	-39619.511	2634027.523	992.067	975.175
A09220054	-39865.046	2635889.735	995.037	978.101
A09220056	-41376.086	2642613.232	1024.281	1007.223
A09220057	-41143.582	2643611.552	1033.240	1016.164
A09220058	-40696.876	2645598.953	1035.917	1018.830
A09220059	-40260.747	2647525.829	1029.867	1012.774
A09220060	-39840.527	2649408.140	1010.867	993.778
A09220061	-40083.019	2651345.223	1004.966	987.849
A09220062	-40413.038	2653279.106	998.001	980.843
A09220063	-40753.721	2655246.361	980.899	963.695
A09220064	-41079.776	2657136.394	956.367	939.138
A09220065	-41407.659	2659084.863	966.759	949.501
A09220066	-41741.660	2661060.358	966.339	949.020
A09220067	-42090.153	2663045.922	959.358	941.995
A09220068	-42423.538	2664995.636	940.012	922.587
A09220069	-42896.105	2666938.495	972.030	954.543
A09220070	-43388.166	2668884.884	970.865	953.314
A09220071	-43912.648	2670919.483	967.856	950.238
A09220072	-44414.378	2672865.317	987.363	969.684
A09220073	-44924.858	2674843.419	995.117	977.371
A09220074	-45424.247	2676777.731	998.684	980.868
A09220075	-45701.712	2678737.364	1006.075	988.202
A09220076	-45689.394	2680742.265	1011.212	993.310
A09220077	-45672.879	2682660.636	1020.294	1002.331
A09220078	-45653.064	2684672.881	1030.394	1012.347
A0922078A	-45634.524	2686699.964	1038.149	1020.007
A09220079	-45639.377	2687573.623	1035.667	1017.526
A09220080	-45606.226	2689648.766	1030.744	1012.530
A09220081	-45587.501	2691670.933	1038.536	1020.250
A09220082	-45566.713	2693673.937	1052.987	1034.620
A09220083	-45548.960	2695629.482	1057.008	1038.580
A09220084	-45532.287	2697763.687	1058.579	1040.060
A09220085	-44308.035	2698751.636	1070.305	1051.790
A09220086	-42378.166	2699633.610	1094.900	1076.440
A09220088	-40654.126	2700407.550	1094.399	1075.970
A09220089	-41266.495	2702420.232	1119.038	1100.503
A09220090	-39395.870	2702898.007	1136.525	1118.065
A09220091	-38407.277	2703541.585	1104.083	1085.615
A09220092	-36423.735	2704384.662	1071.058	1052.662
A09220093	-34503.158	2705275.135	1041.757	1023.392
A09220094	-32846.645	2706032.699	1021.730	1003.389
A09220095	-31573.816	2706615.006	1007.496	989.164
A09220096	-30234.960	2707329.199	995.110	976.795
A09220097	-31483.432	2708763.584	1005.929	987.490
A09220099	-25073.577	2709812.394	955.531	937.232
A09220100	-26006.708	2711162.069	951.238	932.867
A09220101	-27427.448	2713169.529	957.834	939.335
A09220102	-28471.850	2714615.660	961.271	942.651
A09220103	-29777.234	2716399.931	969.958	951.191
A09220104	-30853.938	2717896.259	975.797	956.898
A09220105	-29645.158	2718437.672	960.107	941.196
A09220106	-27771.194	2718843.427	932.784	913.907
A09220107	-25975.184	2719365.481	918.546	899.713
A09220108	-23773.759	2720322.489	922.988	904.130
A09220109	-25526.116	2720949.637	916.309	897.385
A09220110	-26897.473	2722208.900	919.530	900.483
A09220111	-28677.574	2722889.345	926.879	907.738
A09220112	-30363.657	2724101.522	922.773	903.506
A09220113	-31596.452	2725329.118	927.198	907.809

A09220114	-31706.643	2726881.096	961.129	941.673
A09220115	-31702.392	2728821.028	931.053	911.482
A09220116	-32408.318	2730544.157	932.580	912.882
A09220117	-32768.666	2731162.899	930.378	910.657
A09220118	-33700.544	2730777.579	941.207	921.477
A09220119	-35026.472	2730439.200	954.928	935.197
A09220120	-37248.632	2729808.882	935.937	916.190
A09220121	-38431.175	2728165.774	928.530	908.845
A09220122	-38077.672	2726051.101	930.740	911.164
A09220123	-39463.337	2724432.201	951.812	932.261
A09220126	-34241.284	2722286.566	1023.065	1003.809
A09220127	-32658.295	2721001.488	996.387	977.245
A09220128	-31603.716	2719732.969	975.225	956.183
A09220129	-32930.718	2732865.306	931.815	911.998
A09220130	-33024.542	2735035.468	934.193	914.256
A09220131	-33041.080	2736688.400	946.995	926.974
A09220141	-43825.677	2737133.476	937.843	917.684
A09220142	-44229.595	2735173.535	933.588	913.514
A09220143	-44355.941	2733247.960	933.698	913.691
A09220144	-44419.725	2731267.895	934.418	914.501
A09220145	-44497.733	2729254.410	944.860	925.014
A09220146	-42169.261	2729013.002	942.049	922.250
A09220147	-40195.456	2728327.246	931.641	911.915
A09220148	-45696.924	2729134.875	945.311	925.423
A09220149	-47163.536	2730080.799	936.514	916.588
A09220150	-47522.133	2731321.335	940.245	920.257
A09220157	-43396.964	2739031.186	940.264	920.021
A09220158	-40453.834	2698162.424	1097.862	1079.530
A09220159	-40271.015	2696112.114	1090.672	1072.408
A09220160	-40087.415	2694051.866	1080.205	1062.009
A09220161	-39833.998	2692155.490	1068.302	1050.182
A09220162	-39289.044	2690175.781	1053.215	1035.183
A09220163	-40653.097	2689621.690	1055.366	1037.321
A09220164	-42304.389	2688947.886	1060.735	1042.660
A09220165	-44242.166	2688157.415	1041.470	1023.348
A09220172	-32758.081	2710233.025	1021.757	1003.201
A09220173	-33263.011	2710838.991	1033.843	1015.233
A09220174	-31312.612	2711618.293	1001.335	982.768
A09220175	-29219.381	2712453.068	974.512	955.989
A09220176	-36467.809	2722355.764	1013.992	994.663
A09220180	-39836.482	2719876.374	1013.559	994.240
A09220181	-39841.281	2718582.023	1042.082	1022.825
A09220182	-40414.860	2716743.624	1086.881	1067.687
A09220183	-40618.308	2714753.548	1151.164	1132.038
A09220184	-41426.514	2713379.888	1100.267	1081.163
A09220185	-41946.888	2711494.768	1089.507	1070.499
A09220186	-42154.969	2709499.021	1086.575	1067.665
A09220187	-42407.385	2707514.289	1103.848	1085.034
A09220188	-42338.014	2705814.645	1118.742	1100.012
A09220189	-41986.233	2703922.063	1115.846	1097.215
A09220212	-57245.915	2778158.195	970.130	948.092
MKDW2	-73283.434	2653074.815	895.236	877.403
SMCA084101	-36423.362	2636050.390	1000.751	983.889
SMCA084803	-28151.854	2622787.661	930.602	914.097
SMCA084804	-35400.869	2620448.030	924.395	907.860
SMCA084805	-43068.830	2622964.189	946.238	929.605
SMCA084806	-50757.343	2623175.646	931.054	914.387
SMCA084809	-40764.132	2639587.920	994.253	977.281
SMCA092001	-73217.005	2653177.620	895.036	877.220

Appendix 2 coordinates from 2019 Trail survey

Coordinate system: Hartebeesthoek94 WG27

Name	Y	X	Known Z	Laser Z	Dz
A09220031	51610.738	-2623074.563	918.432	918.420	-0.012
A09220057	41143.582	-2643611.552	1016.164	1016.180	+0.016
A09220060	39840.527	-2649408.140	993.778	993.890	+0.112
A09220061	40083.019	-2651345.223	987.849	987.940	+0.091
A09220062	40413.038	-2653279.106	980.843	980.930	+0.087
A09220063	40753.721	-2655246.361	963.695	963.720	+0.025
A09220064	41079.776	-2657136.394	939.138	939.140	+0.002
A09220065	41407.659	-2659084.863	949.501	949.510	+0.009
A09220066	41741.660	-2661060.358	949.020	949.120	+0.100
A09220067	42090.153	-2663045.922	941.995	942.070	+0.075
A09220068	42423.575	-2664995.659	922.587	922.600	+0.013
A09220069	42896.105	-2666938.495	954.543	954.480	-0.063
A09220070	43388.202	-2668884.942	953.314	953.420	+0.106
A09220071	43912.648	-2670919.483	950.238	950.260	+0.022
A09220072	44414.411	-2672865.323	969.684	969.720	+0.036
A09220073	44924.858	-2674843.419	977.371	977.430	+0.059
A09220075	45701.712	-2678737.364	988.202	988.240	+0.038
A09220076	45689.394	-2680742.265	993.310	993.340	+0.030
A09220077	45672.879	-2682660.636	1002.331	1002.390	+0.059
A09220078	45653.098	-2684672.895	1012.347	1012.410	+0.063
A09220078A	45634.554	-2686700.016	1020.007	1019.990	-0.017
A09220080	45606.226	-2689648.766	1012.530	1012.520	-0.010
A09220081	45587.501	-2691670.933	1020.250	1020.260	+0.010
A09220082	45566.713	-2693673.937	1034.620	1034.660	+0.040
A09220085	44308.035	-2698751.636	1051.790	1051.760	-0.030
A09220086	42378.166	-2699633.610	1076.440	1076.450	+0.010
A09220088	40654.126	-2700407.550	1075.970	1075.940	-0.030
A09220089	41266.495	-2702420.232	1100.503	1100.430	-0.073
A09220090	39395.870	-2702898.007	1118.065	1118.050	-0.015
A09220096	30234.960	-2707329.199	976.795	976.880	+0.085
A09220101	27427.448	-2713169.529	939.335	939.420	+0.085
A09220102	28471.850	-2714615.660	942.651	942.670	+0.019
A09220103	29777.234	-2716399.931	951.191	951.100	-0.091
A09220104	30853.969	-2717896.288	956.898	956.840	-0.058
A09220113	31596.402	-2725329.102	907.809	907.660	-0.149
A09220127	32658.295	-2721001.488	977.245	977.090	-0.155
A09220128	31603.716	-2719732.969	956.183	956.020	-0.163
A09220310A	41588.260	-2641621.410	992.750	992.830	+0.080
A09220312	42485.900	-2637657.580	954.410	954.440	+0.030
A09220313	42924.430	-2635660.900	948.950	949.040	+0.090
A09220314	43373.690	-2633701.120	937.730	937.790	+0.060
A09220315	43813.730	-2631709.480	940.250	940.320	+0.070
A09220317	43997.400	-2630881.800	937.340	937.420	+0.080
A09220317A	42907.040	-2629174.900	949.620	949.630	+0.010

SGP2019_43_V02_GibbBigenNyeletiJointVenture_MokoloCrocodileWaterAugmentationProject_FinalSurveyReport

Southern Mapping Geospatial (Pty) Ltd

Revision0

Page 16 of 17



Reg. No. 2010/010712/07
 Directors: N Banks (Chairman),
 J P Engelke, J S Vaughan
www.southernmapping.com

Appendix 3



518 CLIFF AVE
WATERKLOOF RIDGE X2
PRETORIA
T: +27 12 347-7879
E: jacow@trailsurveys.com





BEACON CONSTRUCTION VERIFICATION REPORT







PROJECT REF CONTRACT NO: 2A-C-111E-02







SURVEYOR G.C. SNYMAN (GTg ES0618)







PROJECT DESCRIPTION MOKOLO CROCODILE WATER AUGMENTATION PROJECT - MCWAP PHASE 2







DATE SURVEYED 18 - 23 NOVEMBER 2019







Beacon Number	Beacon Appearance	Beacon Tag	Beacon Stability	Vegetation Cleaned	Demarcation	Photo #1	Photo #2	COMMENTS
A09220127	Good	Good	Good	Yes	Pre-marked - Y Cross, stones painted white			Acceptable Condition
A09220104	Good	Good	Good	Yes	Cairn of Stones - painted white			Acceptable Condition







A09220103	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition Beacon located approximately 0.4m below natural ground level
A09220102	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition Beacon located approximately 0.5m below natural ground level
A09220128	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Not Acceptable Condition







A09220113	Good	Good	Good	Yes	Cairn of Stones - painted white			Acceptable Condition
A09220101	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220096	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220095	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220094	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220093	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon







A09220092	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220091	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220073	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220072	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220071	Concrete Sides Damaged	Tag removed	Peg is Stable	Yes	Pre-marked - Y Cross, stones painted white			Not Acceptable Condition
A09220070	Cracks	Good	Peg is Stable	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220069	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220068	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220067	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220066	Cracks	Good	Peg is Stable	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220089	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220088	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220086	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220085	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220082	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220081	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220080	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220078A	Cracks	Damaged one Side	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220078	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220077	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220076	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220075	Concrete Sides Damaged	Tag Removed	Peg is Stable	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Not Acceptable Condition
A09220074	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220079	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon







A09220083	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220084	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220056	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon







A09220310A	Good	Numbers not visible	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220311	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A09220312	Cracks	Numbers not visible	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220313	Cracks	Good	Good	Yes	Pre-marked - Y Cross, stones painted white			Acceptable Condition
A09220314	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220315	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220317	Good	Numbers not visible	Good	Yes	Cairn of Stones - painted white			Acceptable Condition
A09220317A	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A0922032A	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon







A0922033	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A0922034	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon
A0922035	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon







A09220065	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220064	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220063	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition







A09220062	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220061	Cracks	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220060	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition





A09220031	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition
A09220059	New	Good	Good	Yes	Cairn of Stones - painted white			New beacon
A09220058	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon

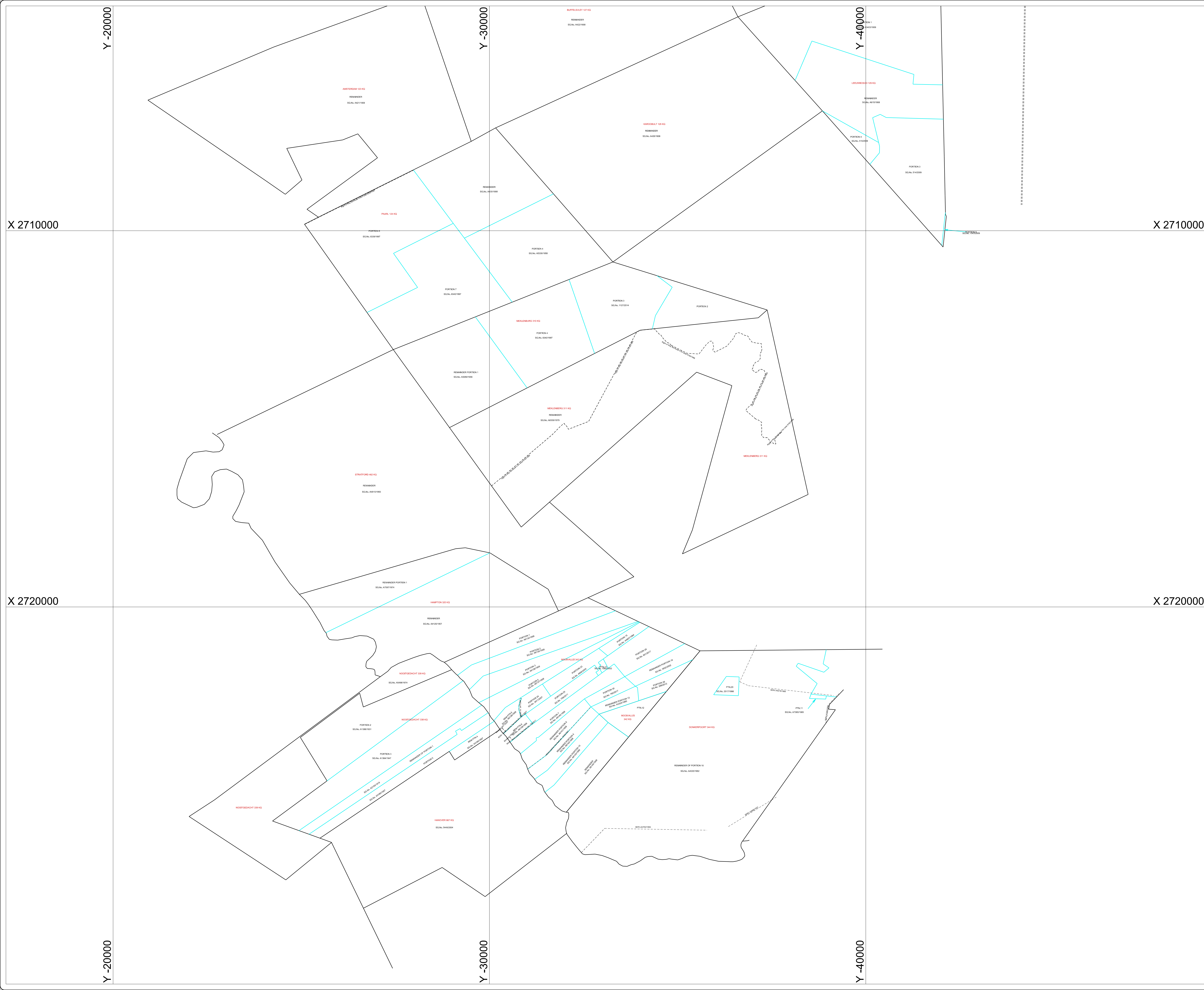
A09220032	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon to be Build
A09220024	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon to be Build
A09220022	New	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			New beacon to be Build

MCWAP 1	Good	Good	Good	Yes	Cairn of Stones - painted white			NEW BEACON	
MCWAP 2	Good	Good	Good	Yes	Cairn of Stones - painted white			NEW BEACON	
MCWAP 3	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			Acceptable Condition	

MCWAP 4	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	
MCWAP 5	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	
MCWAP 6	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	

MCWAP 8	Good	Good	Good	Yes	Cairn of Stones - painted white			NEW BEACON	
MCWAP 9	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	
MCWAP 10	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	

MCWAP 11	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	
MCWAP 12	Good	Good	Good	Yes	Cairn of Stones - painted white Nearest Fence Pole painted white			NEW BEACON	



GENERAL NOTES:
WGS84 L027

REVISION HISTORY:

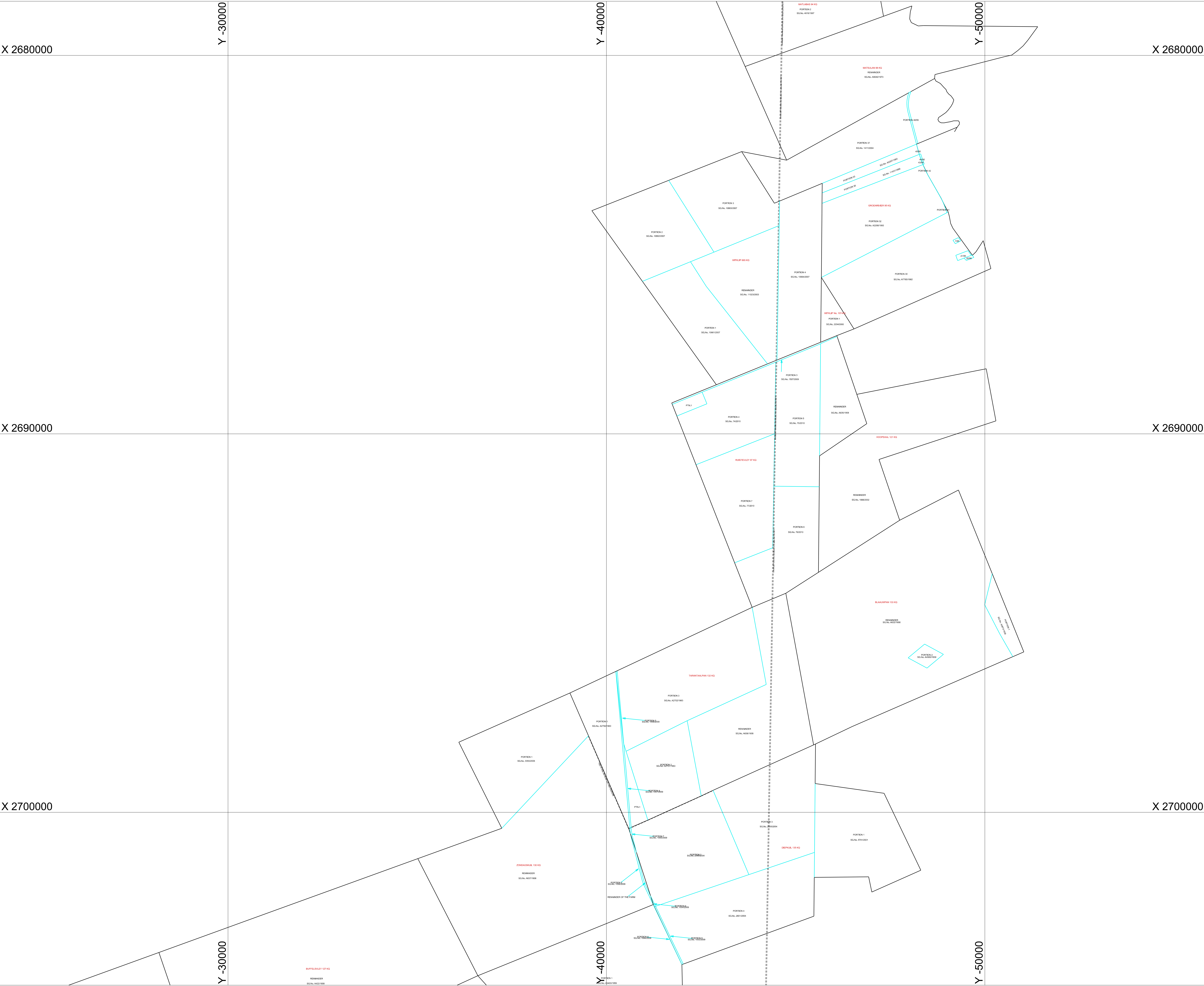
REV	DESCRIPTION

CLIENT:
SMC

DRAWING TITLE:
MOKOLO PIPE CADASTRAL

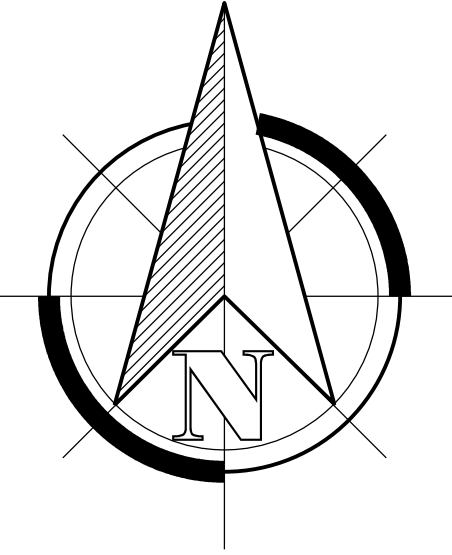
SURVEYOR: TRAIL SURVEYS
SURVEY DATE: OCTOBER 2019
DRAUGHTSMAN: T.DORFLING
MAPPING DATE: 2019/11/04
SCALE: 1:----
SHEET No: 1 OF 6
REVISION: 0

TRAIL SURVEYS
518 CLIFF AVE
WATERKLOOF RIDGE
PRETORIA
SOUTH AFRICA
TEL (012) 347-7879
EMAIL: INFO@TRAILSURVEYS.COM



GENERAL NOTES:
WGS84 LQ27

REVISION HISTORY:	
REV	DESCRIPTION



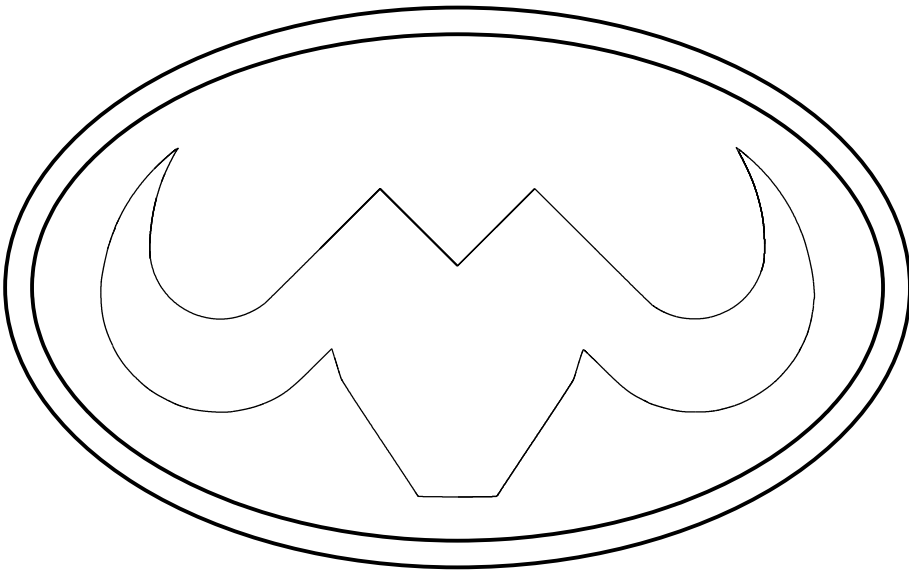
CLIENT:

SMC

DRAWING TITLE:

MOKOLO PIPE CADASTRAL

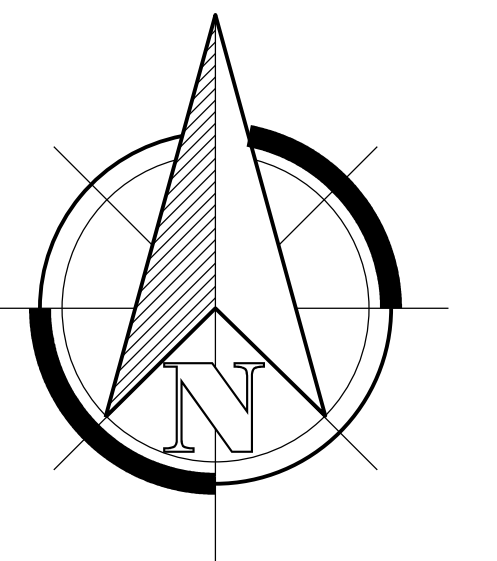
SURVEYOR: TRAIL SURVEYS
SURVEY DATE: OCTOBER 2019
DRAUGHTSMAN: T.DORFLING
MAPPING DATE: 2019/11/04
SCALE: 1:----
SHEET No: 2 OF 6
REVISION: 0



TRAIL SURVEYS
518 CLIFF AVE
WATERKLOOF RIDGE
PRETORIA
SOUTH AFRICA
TEL (012) 347-7879
EMAIL: INFO@TRAILSURVEYS.COM

WGS84 L027

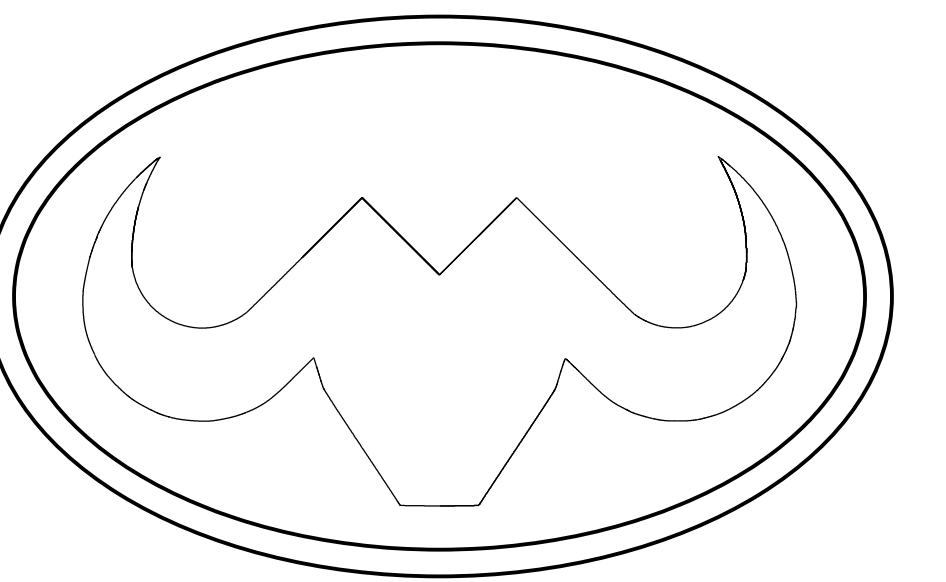
REV	DESCRIPTION



SMC

MOKOLO PIPE CADASTRAL

REVISION: 0



518 CLIFF AVE
WATERKLOOF RIDGE
PRETORIA
SOUTH AFRICA
TEL (012) 347-7879
EMAIL: INFO@TRAILSURV

X 2630000

Y -30000

X 2630000

Y -50000

X 2640000

X 2640000

X 2650000

X 2650000

Y -30000

Y -40000

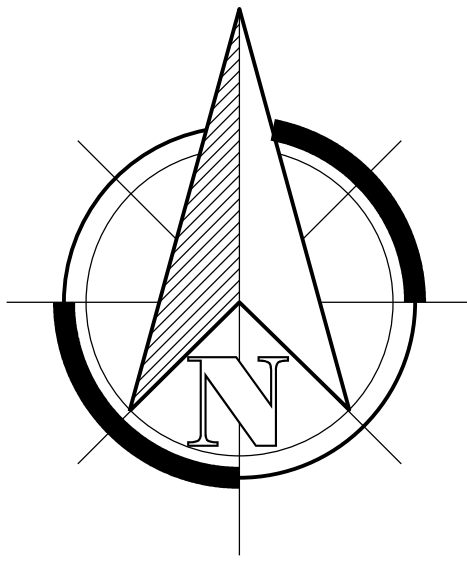
Y -50000

GENERAL NOTES:

WGS84 L027

REVISION HISTORY:

REV	DESCRIPTION



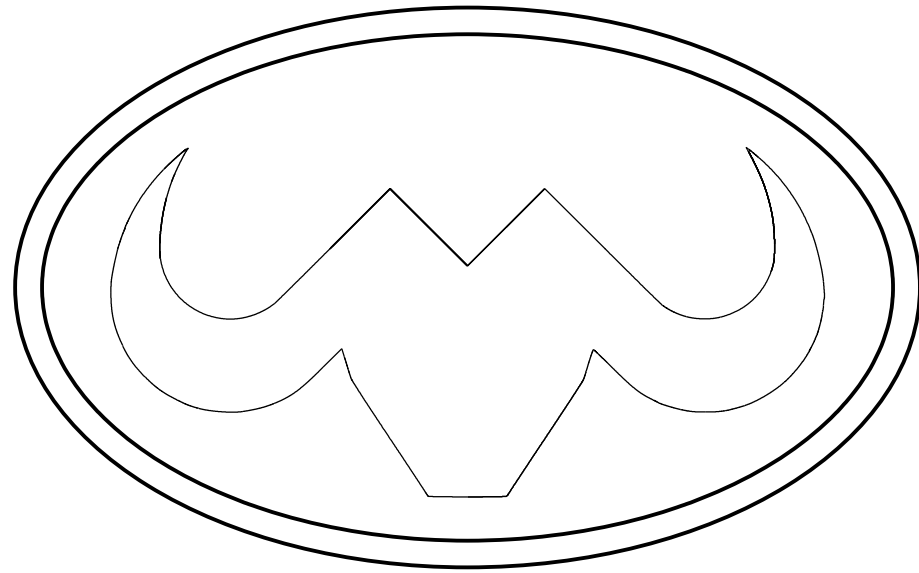
CLIENT:

SMC

DRAWING TITLE:

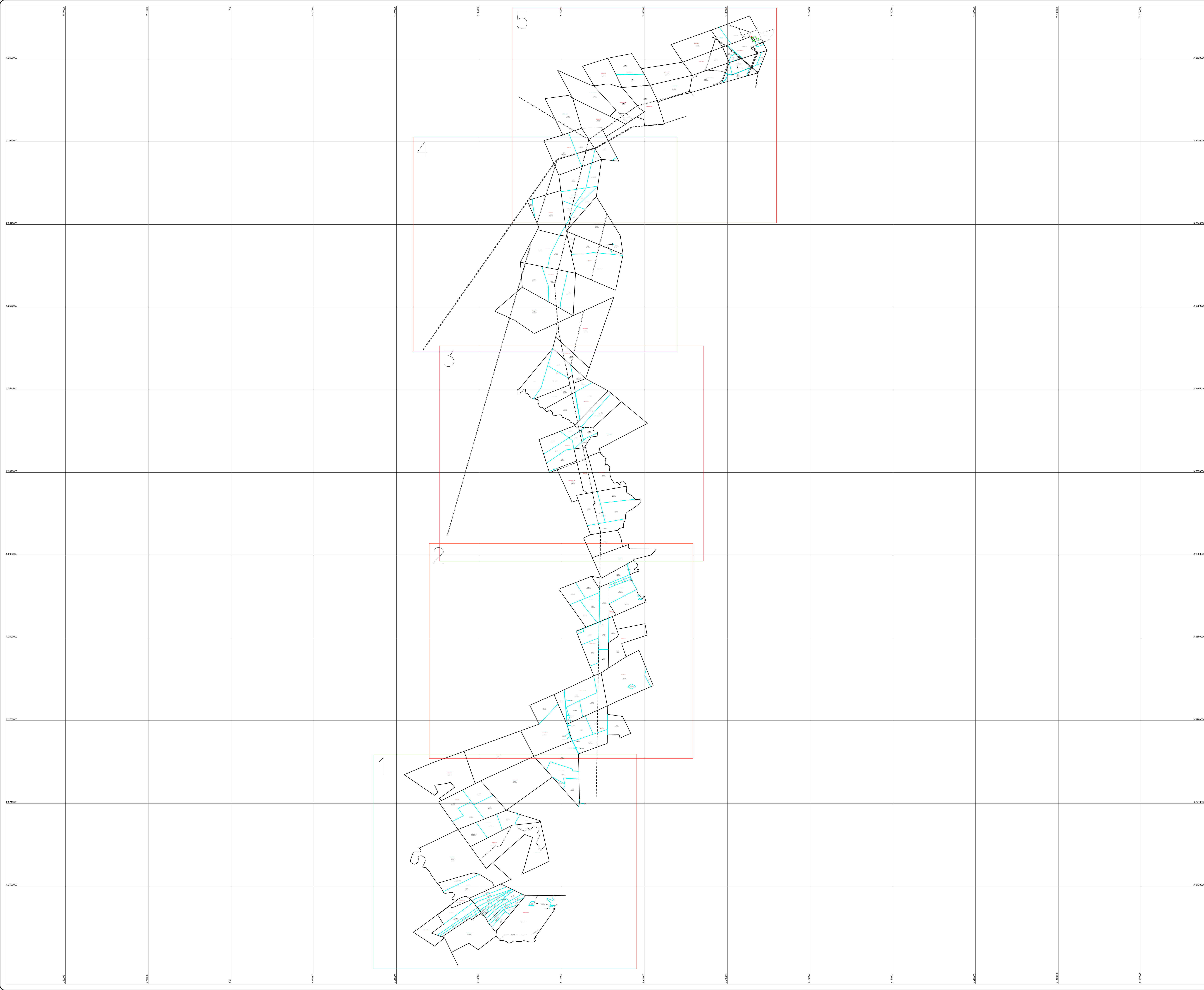
MOKOLO PIPE CADASTRAL

SURVEYOR: TRAIL SURVEYS
SURVEY DATE: OCTOBER 2019
DRAUGHTSMAN: T.DORFLING
MAPPING DATE: 2019/11/04
SCALE: 1:----
SHEET NO: 4 OF 6
REVISION: 0



TRAIL SURVEYS

518 CLIFF AVE
WATERKLOOF RIDGE
PRETORIA
SOUTH AFRICA
TEL (012) 347-7879
EMAIL: INFO@TRAILSURVEYS.COM



GENERAL NOTES:

WGS84 L027

REVISION HISTORY:

REV	DESCRIPTION

CLIENT:

SMC

DRAWING TITLE:

MOKOLO PIPE CADASTRAL

SURVEYOR: TRAIL SURVEYS

SURVEY DATE: OCTOBER 2019

DRAUGHTSMAN: T.DORFLING

MAPPING DATE: 2019/11/04

SCALE: 1:----

SHEET No: 6 OF 6

REVISION: 0

TRAIL SURVEYS

518 CLIFF AVE

WATERKLOOF RIDGE

PRETORIA

SOUTH AFRICA

TEL (012) 347-7879

EMAIL: INFO@TRAILSURVEYS.COM